RAISING WITH A SUSPENDED WORK CAGE AT THE IRENE SHAFT, LEADVILLE, COLO.

BY R. L. BOLMER AND B. B. GREENLEE

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RAISING WITH A SUSPENDED WORK CAGE AT THE IRENE SHAFT, LEADVILLE, COLO.[1/]

by

R. L. Bolmer[2/] and B. B. Greenlee[3/]

SUMMARY AND INTRODUCTION

Driving long development raises probably is one of the most hazardous and expensive operations in underground mining. The safe handling of men and materials becomes more difficult and more time consuming in the higher sections of the raise. The efficient ventilation of these sections often is a major problem. This information circular describes a unique method by which Resurrection Mining Co. safely and efficiently completed a 622-foot vertical raise at its Irene shaft near Leadville, Colo.

The method used by the company involved driving a raw, 6-foot-diameter ventilation raise and emergency escapeway, using a work cage that was suspended on a hoisting rope extended down a small-diameter drill hole. Although the method was new and experimental, the raise was completed in record time. Overall costs were less than they would have been with conventional methods. The company's initial experience suggested improvements both in design and operating technique that should prove of value to others who contemplate using the cage method of raising

ACKNOWLEDGMENTS

The cooperation and assistance of the management and staff of the Resurrection Mining Co. in preparing this information circular are gratefully acknowledged. Special acknowledgment is made to C. N. Stout, general foreman, and Harry Chapman, shift boss, who were directly responsible for the success of the raise.

LOCATION

The Irene shaft is in the central part of the Leadville mining district, approximately 3 miles east of Leadville, Lake County, Colo. The shaft collar and mine surface plant are at an altitude of 11,630 feet.

EMPLOYMENT AND PRODUCTION

The mining operations at the Irene shaft were a joint venture of American Smelting and Refining Co. and Resurrection Mining Co. The latter company, a subsidiary of Newmont Mining Corp., managed the operations. About 85 men were employed underground. Approximately 12,000 tons of lead-zinc-copper-silver ore was produced monthly.

MINE DEVELOPMENT

The Irene shaft was sunk vertically 1,855 feet below the surface. Two main operating laterals - the 1600 and 1750 levels - were turned from the shaft at depths

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1/ Work on manuscript completed June 1958.
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of 1,655 and 1,806 feet, respectively. These levels were interconnected through development raises and stopes. At a depth of 1,042 feet the shaft was connected by a crosscut with the 1000 or lowest working level of the nearby Eclipse shaft.

PURPOSE OF RAISE

The development contemplated along the lower levels would require more air than could be supplied by the existing ventilating system. A raise connection to the 1000 level from the limits of development on the 1600 level would increase ventilating efficiency, permit removal of most of the flexible tubing used in ventilating the shaft and levels, and serve as an emergency escapeway from the lower sections of the mine.

Prior to completion of the raise the mine was ventilated by a main fan installed on the 1000-level connection with the Eclipse shaft. The Eclipse shaft was downcast. Intake air was forced to the lower levels through 30-inch flexible tubing extended down the manway compartment of the Irene shaft. Branch lines of 18-inch tubing directed intake air from the shaft to the limits of development along both the 1600 and 1750 levels. Booster fans were needed in the branch lines. Return air coursed along the two levels and exhausted up the shaft. Auxiliary blowers forced part of the return air into stopes above the levels.

RAISING

Existing Facilities

Before development of the property through the Irene shaft went deeper, the lower ore horizons had been explored by diamond drilling from the 1000 level of the Eclipse shaft. One drill hole was at a location suitable for the needed ventilation raise and emergency escapeway. This uncased BX hole extended vertically below the 1600 level, and its drill station had been excavated about 20 feet above the 1000 level. (See fig. 1.)

Planning Stage

The management began to consider the feasibility of driving the raise connection at this location from a work cage suspended on a hoist rope extended down the drill hole. The company previously had completed two short, inclined raises by this method but had no actual experience in driving a long vertical raise, such as now was planned.

An effort was made to obtain all available information on previous experience with this method at other properties. Investigation revealed that the cage method of raising had been used successfully by at least two American companies and one foreign operation. The raises had ranged from 100 to 400 feet in length; all were approximately 6 feet in diameter.

Tennessee Copper Co., Ducktown, Tenn., drove a 100-foot vertical raise by the cage method at its Central shaft in 1953[4/] and subsequently used the technique for extending its Boyd shaft 400 feet.[5/] Zellidja Mines, Bou-Beker, Morocco, reported completion of a 60-meter vertical ore pass by the cage method in 1954. Odanah Iron

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4/ Engineering and Mining Journal, Keeping Tab on Practice - New Raising Technique Developed Experimentally: Vol. 154, No. 6, June 1953, p. 102.

5/ Kopp, G. G., Engineering for Safety - Extension of Boyd Manshaft, Tennessee Copper Co., Ducktown, Tenn.: Nat. Safety Conf., 1955.

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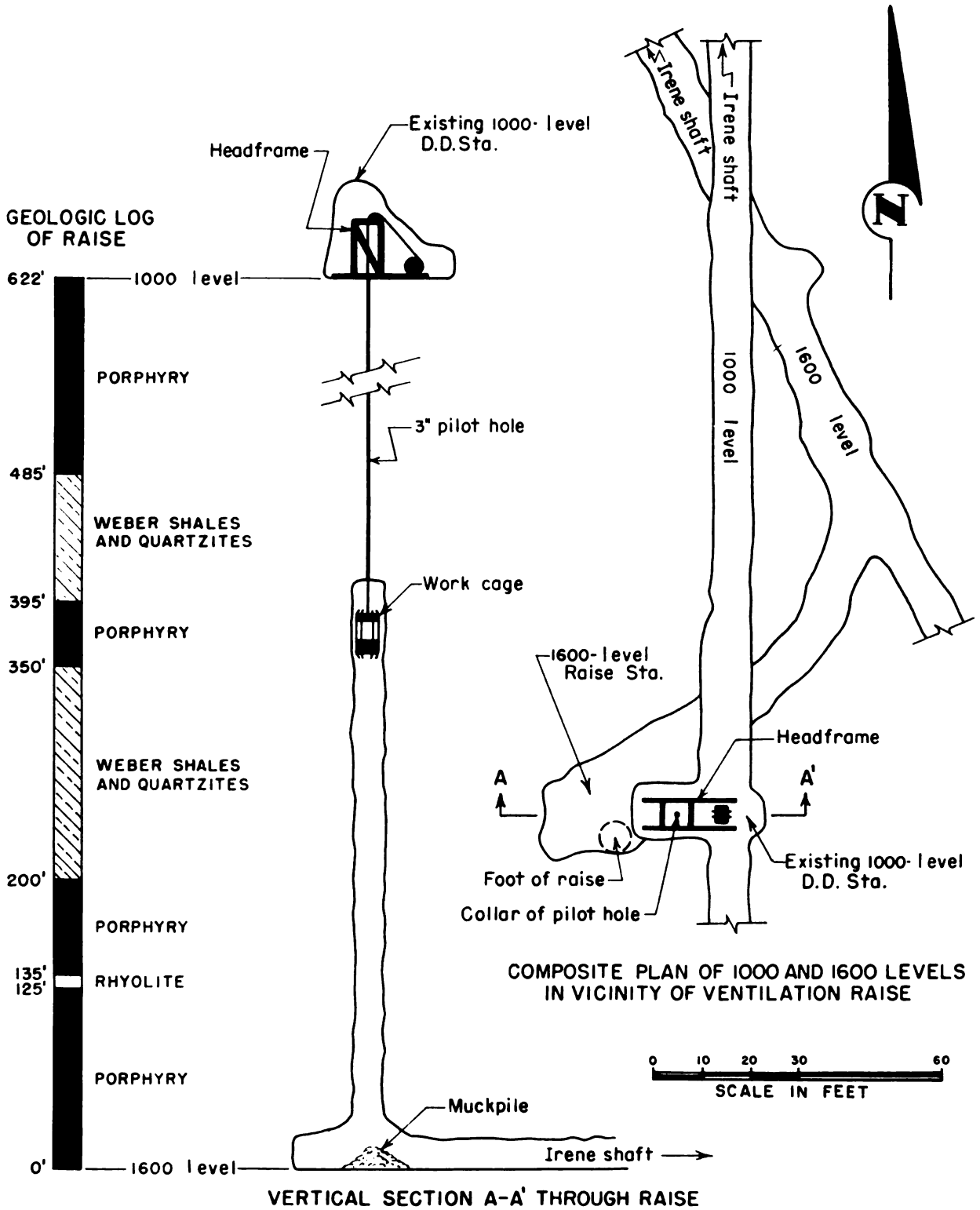

FIGURE 1. - Plan, Section, and Log of Ventilation Raise Driven by Cage Method.

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Co., Hurley, Wis., deepened the main shaft at its Cary mine by driving 2 successive 200-foot vertical pilot raises using this method.6/ Cleveland-Cliffs Iron Co., Ishpeming, Mich., was reportedly preparing to start a raise by the cage method early in 1957.

The Resurrection Mining Co. decided that the cage method of driving the raise connection between the 1600 and 1000 levels was feasible and proceeded with the necessary preparations.

Preparation Period

Reaming and Casing Diamond-Drill Hole

A BX hole was considered too small for passage of the required hoisting rope, with its necessary thimble and clamps. Moreover, it was believed that an uncased hole would not remain open under unstable ground conditions. Therefore, the existing drill hole was reamed to 3-5/8 inches in diameter and provided with NX casing. Considerable difficulty was experienced in reaming the lower sections of the hole through an altered porphyry sill. Only 492 feet of the hole could be reamed and cased.

Preparation of 1600-Level Station

On the 1600 level, a crosscut was driven to intersect the diamond-drill hole and a small station excavated at the intersection. A switch and a short section of double track were laid across the station to facilitate loading rock broken from the raise. A single-drum, air-driven tugger was mounted in the station to pull the work cage to and from the bottom of the raise. A 5-hp. triplex pump also was installed on the level to provide enough water pressure for drilling in upper sections of the raise.

Design and Construction of Work Cage

The work cage was designed by the company staff and constructed in the mine shops. The cage incorporated the better features of working platforms used at other mines with innovations and alterations suggested by the company staff. Sections showing the final design of the work cage are reproduced in the appendix.

The hexagonal work cage was 9-3/4 feet in overall length and 5-1/2 feet in maximum diameter. The all-steel unit weighed 1,910 pounds. It comprised a 3/8-inch steel-plate floor or lower deck, which was supported by six 2-inch pipes spaced equidistantly around its circumference and a single 4-inch pipe through its center. (See fig. 2.) The ends of the enclosing pipe supports were bent inward to minimize the danger of "hang-ups." Because of the resemblance, the unit was referred to as a birdcage.

The sides of the work cage were partly enclosed by lightweight steel plate. The flat bonnet or top deck consisted of 2 semicircular, 1/4-inch plates, each of which could be revolved around the central support pipe to provide the desired opening. (See fig. 3.)

6/ Wangaard, J. C., Driving a Vertical Raise by Use of a Cage, Cary Mine, Odanah Iron Co., Hurley, Wis.: Lake Superior Mines Safety Council, 1957.

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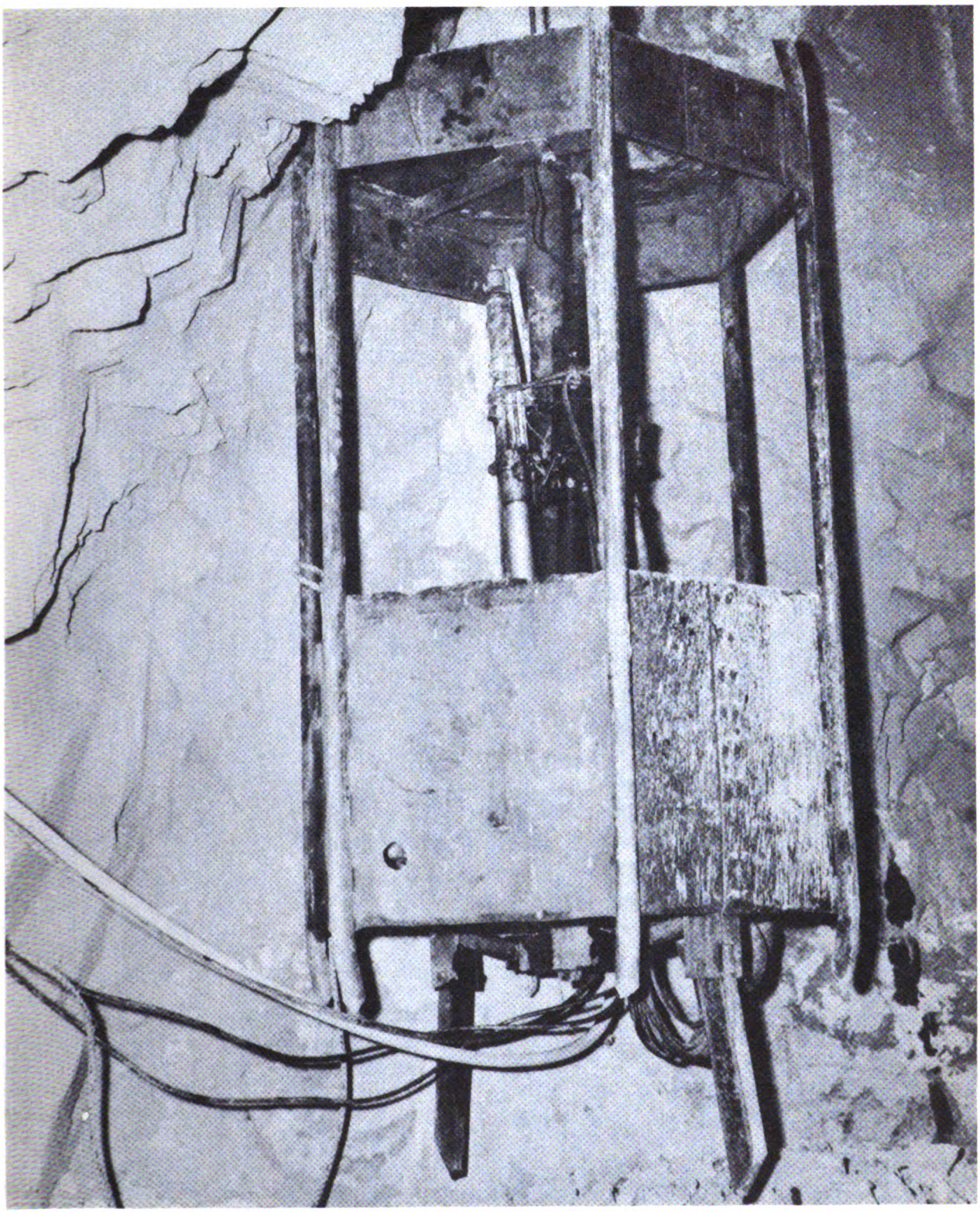

FIGURE 2. - Work Cage Suspended Below Raise in 1600-Level Station.
(Courtesy Resurrection Mining Co.)

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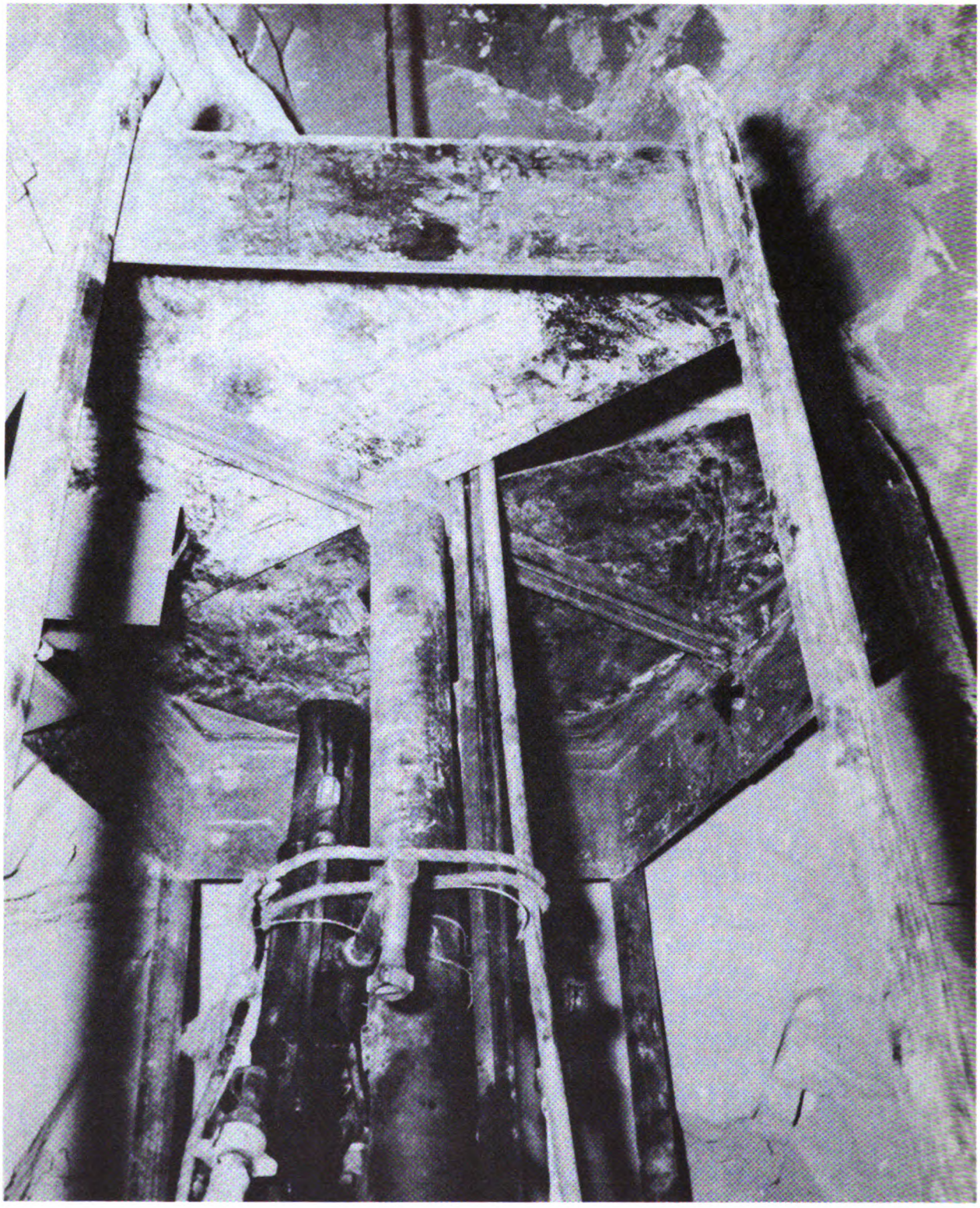

FIGURE 3. - Revolving Steel-Plate Bonnet or Top Deck of Work Cage.
(Courtesy Resurrection Mining Co.)

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The cage was suspended from the hoist rope by a 3-inch rod which extended through the central support pipe. (See fig. 4.) The top of the suspension rod was slotted to fit a coupling connected to the thimble on the rope. A falling pin linked the coupling to the rod. The main frame of the cage was secured to the central pipe by heavy clamps. The weight of the unit was transferred from the supporting pipe to the hoist rope by means of a key inserted through the lower end of the suspension rod.

Spring-actuated safety dogs were mounted under the lower deck on opposite sides of the cage. (See fig. 5.) The dogs were linked to the key in the bottom of the suspension rod. When tension on the hoist rope was released, the suspension rod dropped and allowed the springs to raise the dogs. Two pneumatic jacks or stingers also were mounted under the lower deck. These were extended against opposite walls of the raise to block the cage during the working cycle.

Signal System for Raise

The work cage was equipped with three independent signal systems. A voice-powered telephone mounted inside the cage (fig. 6) was connected to similar phones on the 1600-level station below the raise and the 1000-level hoist station above the diamond-drill hole. The cage and the 1600- and 1000-level stations also were interconnected by a three-way squawker system. In addition, the cage and the hoist were connected by a direct electrical signal.

The voice and signal systems were transmitted through a multiconductor cable suspended below the work cage. This cable extended along the 1600 level to the Irene shaft, up the shaft to the 1000 level, and along the 1000 level to the hoist station.

1000-Level Headframe and Hoist

A 12-foot, 4-post, steel headframe, which had been designed and fabricated in the mine shops, was erected over the collar of the hole within the existing 1000-level drill station. A 37-1/2-hp., single-drum, geared hoist, which had been reconditioned and modified in the shops to meet the requirements of the raising project, was mounted on the base of the headframe. (See fig. 7.) A shop drawing of the hoist-headframe unit is reproduced in the appendix.

The distance between the hoist drum and the sheave wheel was a minimum. In order not to exceed the recommended fleet angle, the width of the drum was reduced from 20 to 8 inches, and the flanges on the drum were heightened to hold the required length of cable. (See fig. 8.) During the raising period the pinion gear on the motor shaft was reduced to obtain greater torque.

The hoist was geared directly to the motor without a clutch. It was equipped with two band brakes. No level indicator was provided. The hoistman operated the hoist within its lower speed range and stopped and started it on signal from the cage. The hoistman, through experience and by watching the tension on the cable, could determine when the cage started to "hang up."

Approximately 700 feet of 5/8-inch, 18 by 7, preformed, nonrotating wire rope was wound in multiple wraps on the hoist drum. The breaking strength of this rope was 15.3 tons. It had a static safety factor ranging from 9.9 to 11.4 when supporting the fully loaded work cage. Two 8-inch torpedo clamps secured the rope around a standard thimble. (See fig. 4.) The combined weight of the clamps and the

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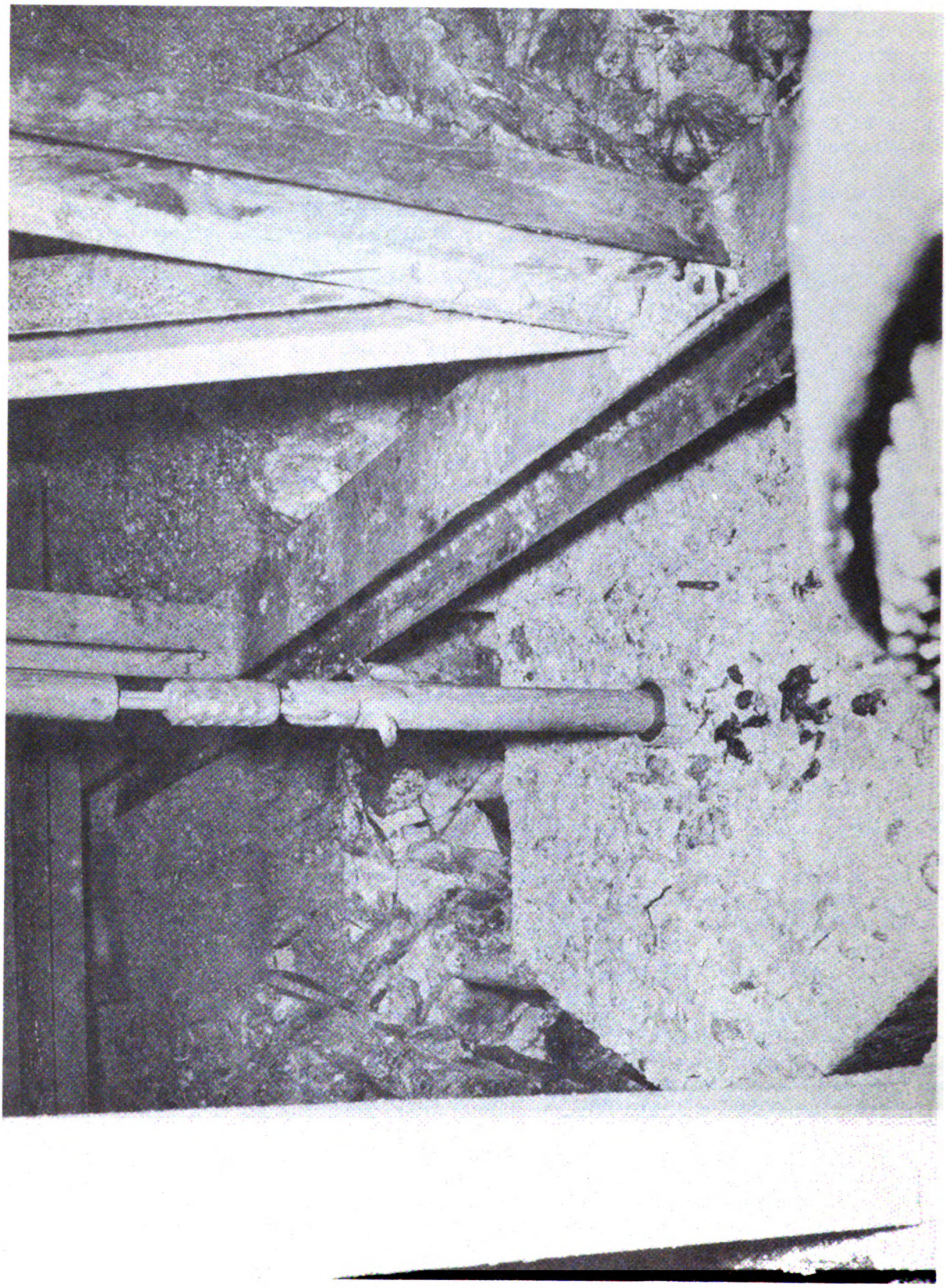

FIGURE 4. - Raise Connection at 1000 Level, Showing Work Cage Suspended Below Headframe.

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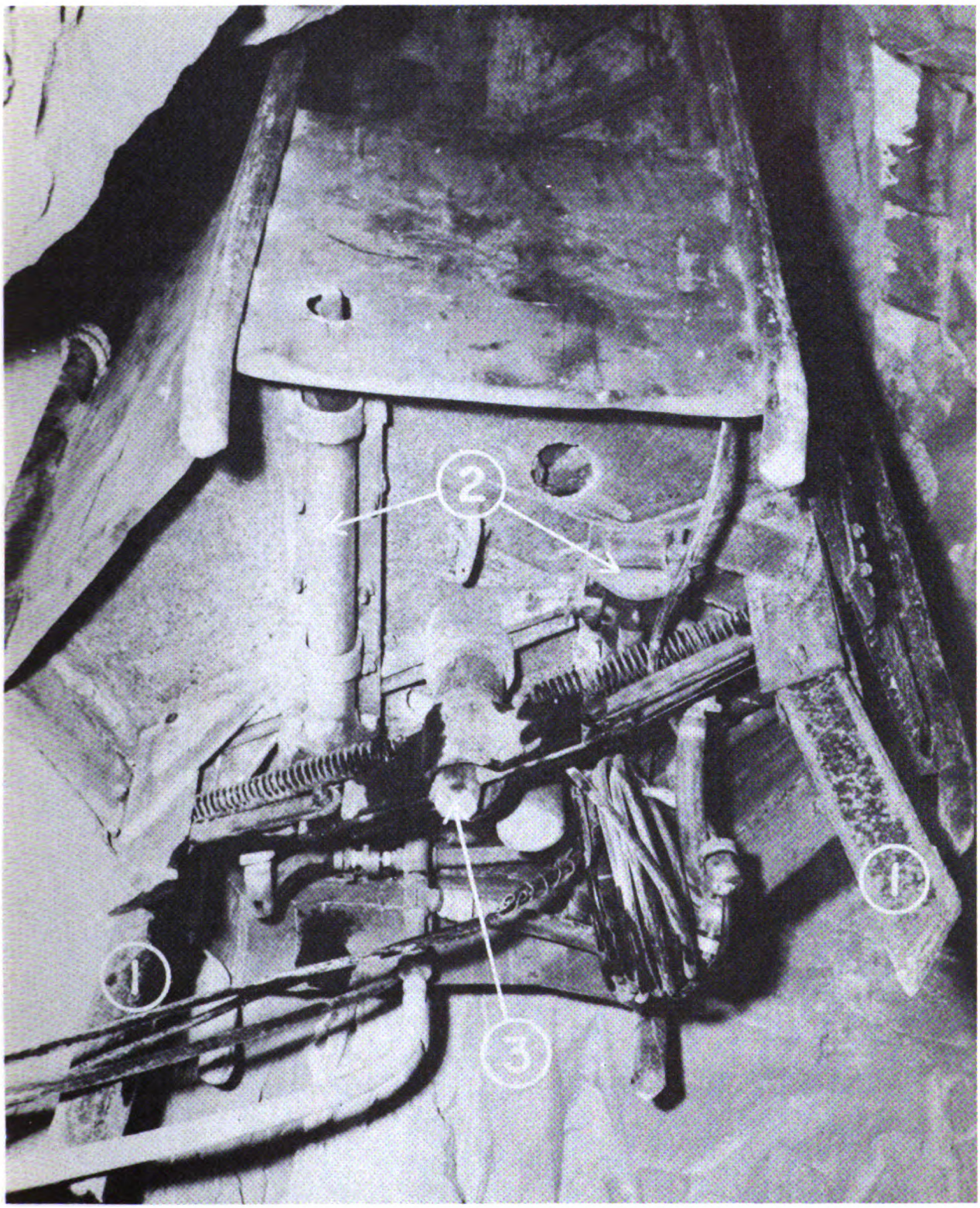

FIGURE 5. - Underside of Work Cage, Showing: (1) Safety Dogs, (2) Air Stingers, and (3) Keyed Suspension Rod. *(Courtesy Resurrection Mining Co.)*

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FIGURE 6. - Overall View of Work Cage Suspended Below Raise in 1600-Level Station, Showing Voice-Powered Telephone Installation.

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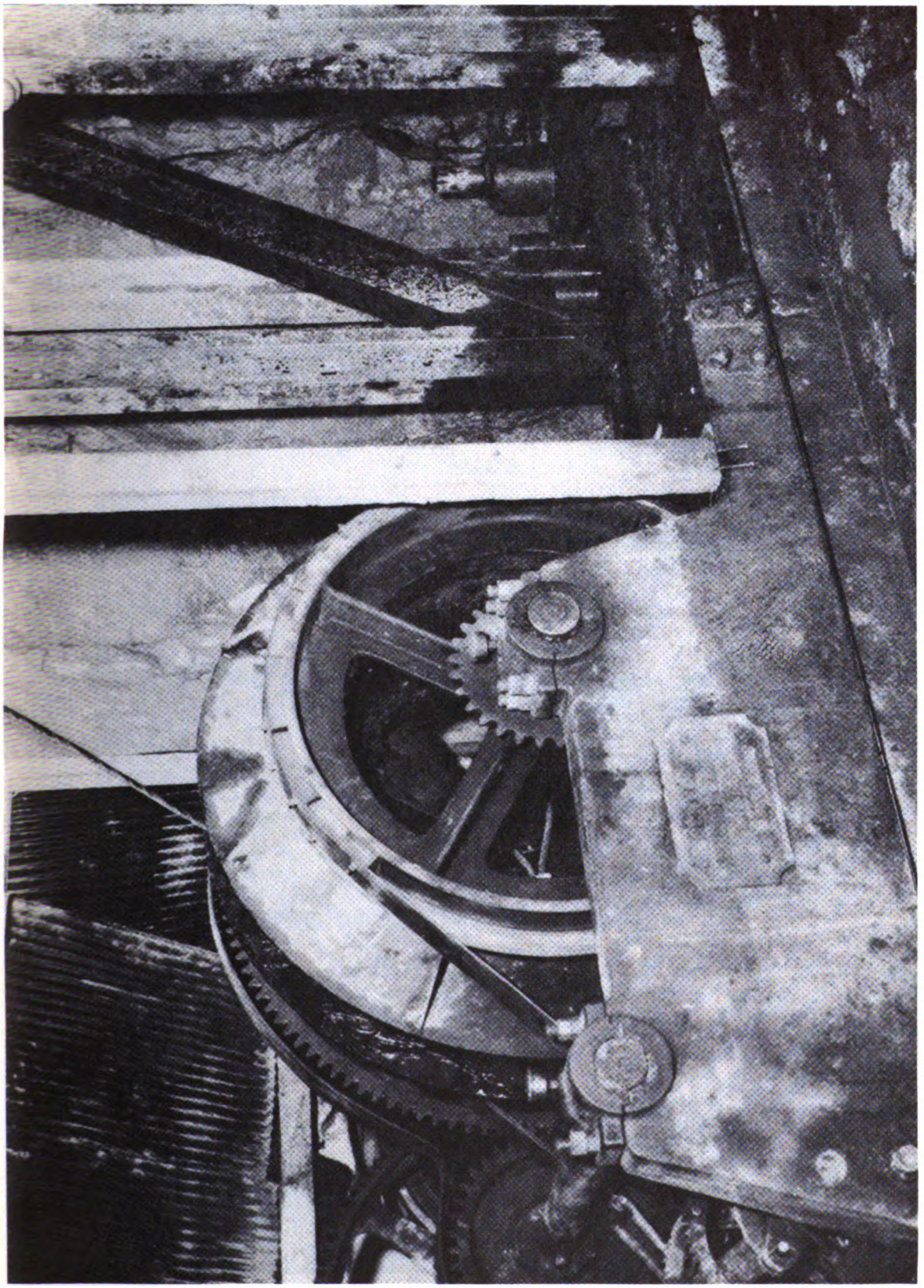

FIGURE 7. - Integral Hoist-Headframe Unit Mounted in Existing 1000-Level Diamond-Drill Station. *(Courtesy Resurrection Mining Co.)*

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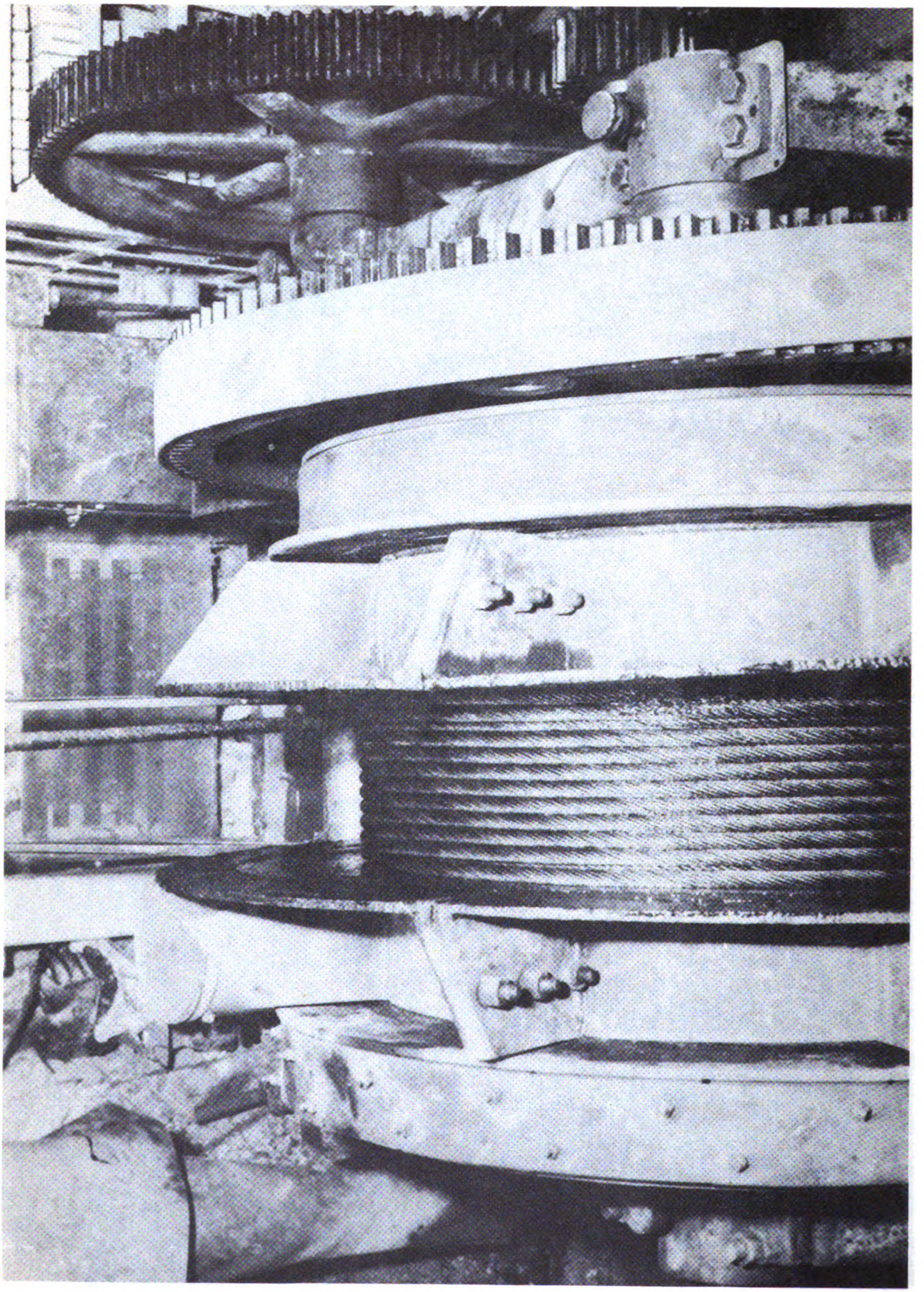

FIGURE 8. • Modified Drum on 1000-Level Hoist.
(Courtesy Resurrection Mining Co.)

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coupling attached to the thimble was enough to start the free end of the rope through the upper sections of the casing.

The NX casing extended a short distance above the collar of the drill hole and was capped with a threaded coupling through which the hoist rope would just pass. (See fig. 9.) This coupling contained connections for attachment to both the compressed-air and water lines. Compressed air was blown down the hole continually during raising.

Preliminary Raising by Conventional Methods

Because of the nature of the ground, it was impractical to ream and case the drill hole more than 492 feet below the 1000 level. The remaining 130 feet of BX hole above the 1600 level was too small for passage of the thimble and clamps on the hoisting rope. Rather than attempting to ream this section of the hole from the lower level, it was believed more feasible to raise the distance by conventional methods. While the work cage was being built and the 100-level headframe and hoist were being installed, a vertical, 6-foot-diameter, stulled raise was driven from the 1600-level station to the bottom of the NX casing.

Raising Period

Actual raising by the cage method was begun 130 feet above the 1600-level track on April 15, 1957. Initially, only one shift was worked per day. The raise had been advanced 41 feet to a height of 171 feet above the level by April 30, 1957.

The first raise round from the work cage was in soft porphyry, and the diamond-drill hole was used for one cut. The initial blast blocked the bottom of the drill hole. Approximately 7-1/2 working days was lost while the hole was reopened. After attempts to reopen the hole from the 1000 level by ordinary means had failed, it was necessary to advance through the plugged section by conventional raising methods. The raise had to be stulled and provided with ladders before the section could be drilled and blasted.

Between May 1 and 15 the raise was driven 152 feet to a height of 323 feet. A second (swing) shift was begun May 8; on May 14 a third (graveyard) shift was added.

The raise holed through to the 1000 level, 622 feet above the 1600 level, on May 29. The last 299 feet of advance was completed in 13-1/6 days, or 39-1/2 working shifts. The average advance was 22.7 feet per day, or 7.6 feet per shift. The raise was driven 56 feet in the final 2-1/6 days.

The 492 feet of raise that was driven with the work cage required 75-1/2 working shifts. The overall average advance, including delay time, was 6.5 feet per shift. A chronological log of the raising period, which summarizes the pertinent operating data and gives the duration and cause of principal delays, is included in the appendix.

After the raise had holed through, it was thoroughly scaled down and gunited. These operations also were carried out with the work cage. The mine was shut down before a steel ladderway could be provided for the raise.

Work Cycle on Day and Swing Shifts

The typical work cycle in the raise on both the day and swing shifts is detailed below. The principal duties performed by the crew are listed chronologically.

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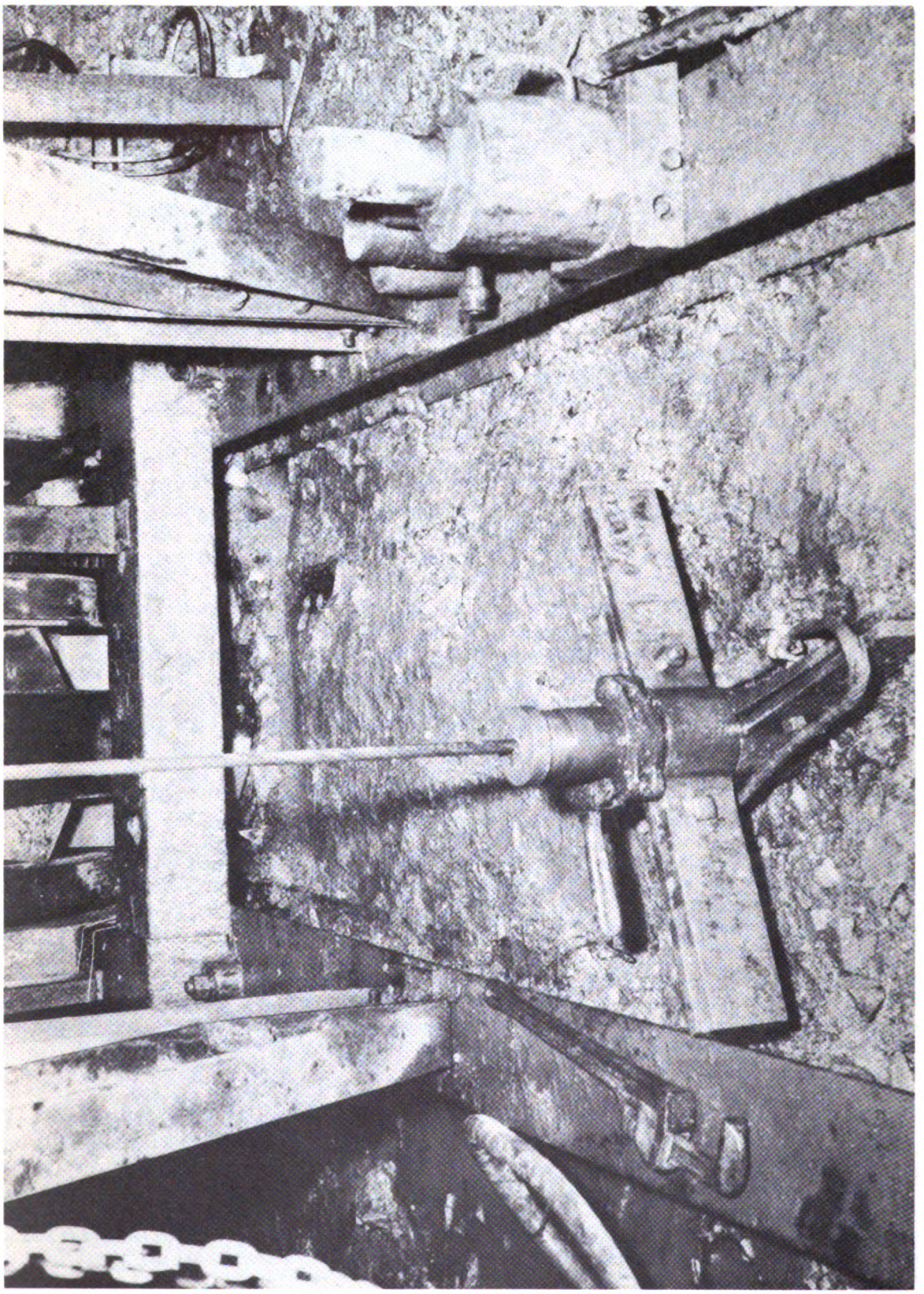

FIGURE 9. - View of 1000-Level Station, Showing Hoist Rope Extending Into Collar of Diamond-Drill Hole Through Coupling on End of NX Casing. *(Courtesy Resurrection Mining Co.)*

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Preparation and Scaling Down

The 1000-level hoistman lowered the hoisting rope through the cased drill hole and the open raise to the 1600-level station where it was coupled to the work cage. The cage was then pulled upright in the station and suspended just above the muck pile from the previous round.

Stopers, drill steel, air and water hose, scaling bars, picks, dynamite and primers in protective containers, blasting wire, and small tools were loaded on the cage. The stopers and drill steel were lashed to the center column. The two-man crew then climbed aboard the lower deck and the cage was hoisted up the raise. (See fig. 10.)

The cage was stopped 15 to 20 feet below the top, and hoses were connected to the ends of the permanent air and water pipes along one side of the raise. The air and water valves on the 1600 level were opened upon signal from the cage.

The cage was then hoisted within 7 feet of the back and stopped. The air stingers were extended to block the cage securely. The top deck was rolled back, and the face was inspected. Any large, loose slabs were scaled down from inside the cage while the crew was still under cover. The crew then climbed through the opening in the top deck and finished scaling down the back and walls of the raise. The top deck, when closed, served as a working platform.

Ordinarily, this preliminary work required 30 to 40 minutes.

Mucking

While the back of the raise was being scaled down, the mucking crew began loading the broken rock from the preceding round which had fallen to the 1600-level track. The average round contained about twelve 30-cubic-foot cars of muck, and the muck was loaded with a standard rocker shovel in approximately 1/2 hour.

Drilling

After the face had been scaled down, the raise crew prepared to drill the next raise round from the top deck of the work cage. Before actual drilling was begun, the men donned safety belts, which were fastened to the hoist rope. The 2-man crew, each using a standard stoper, drilled out a 6-foot raise round in approximately 1 hour.

Loading and Blasting

After the round was drilled, the blast holes were loaded and wired. The circuit was tested and connected to the lead wires. One man climbed to the lower deck and released the stingers on the cage. The second man remained on the top deck and unwound the spool of lead wire as the cage was lowered from the face.

The cage was stopped while the hoses were disconnected from the permanent air and water lines. Then the cage was lowered 50 to 60 feet from the back, and the lead wires were attached to the permanent blasting cable on the rib of the raise alongside the air and water pipes. While the cage was lowered slowly to the 1600 level, the two-man crew inspected the blasting cable for damage and repaired it if necessary.

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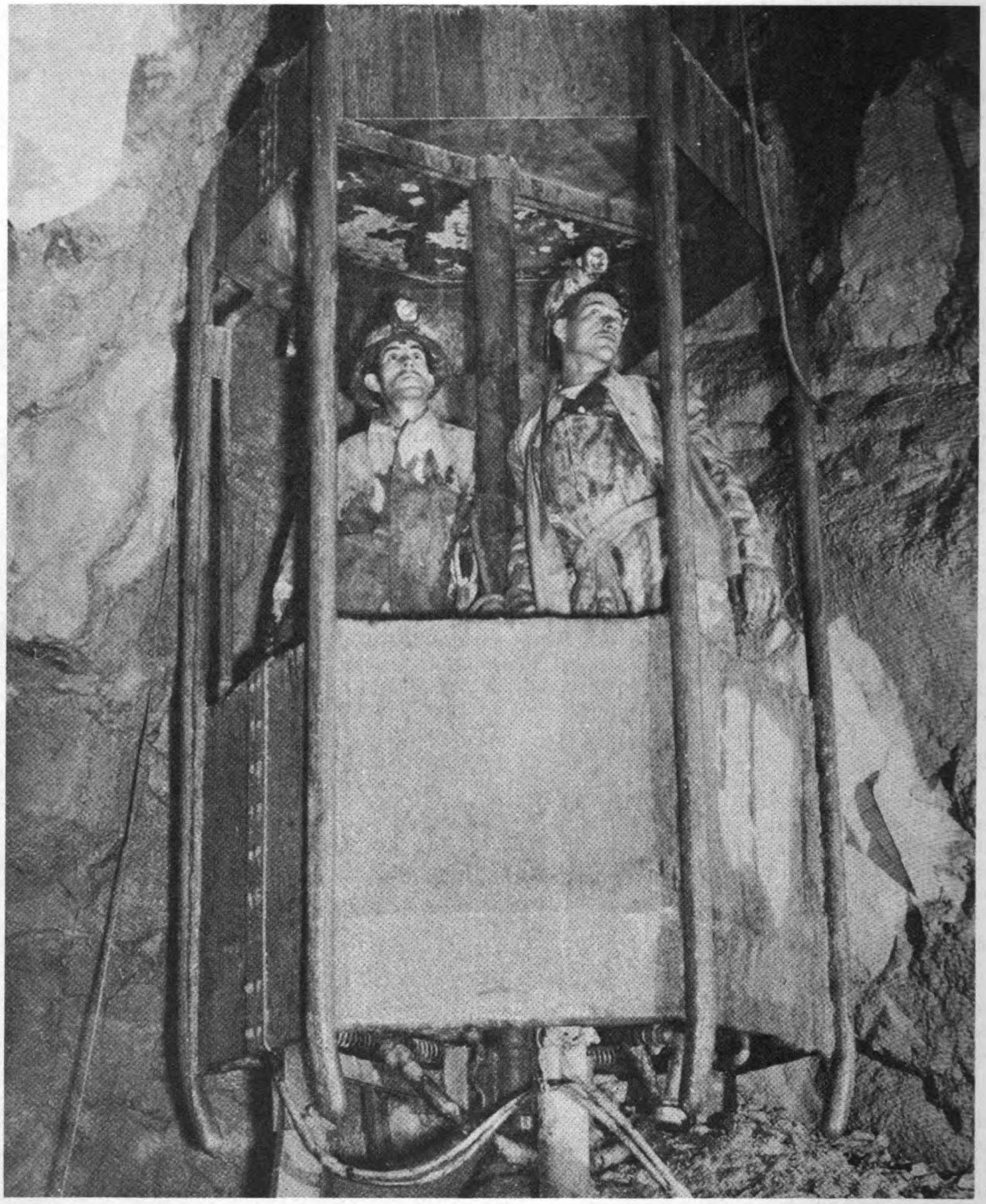

FIGURE 10. - Crew Aboard Work Cage Suspended in 1600-Level Station Preparatory to Being Hoisted to Face of Raise.

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On the 1600 level the work cage was pulled 15 to 20 feet back from the raise by means of the air tugger. The hoist rope was uncoupled and pulled from the drill hole on the 1000 level. After the rope was removed from the hole, the hoistman replaced the coupling on top of the casing and redirected compressed air down the hole. The valves to the permanent air and water lines in the raise were opened before the round was fired from the 1600 level.

Approximately 1 hour was required to load and blast the round.

Ventilation Period

After the round was fired but before the powder smoke had reached the bottom of the raise, the hoist rope was lowered to the 1600 level and recoupled to the cage. The cage was then suspended in the station and loaded with the tools and supplies needed for the next cycle.

The smoke and gas generally cleared from the top sections of the raise within 30 minutes. The crew usually ate lunch during this period and was ready to return up the raise by the time the smoke had reached the level.

Barring delays, a full raising cycle could be completed within 3 to 3-1/2 hours. Two cycles often were completed on both the day and swing shifts.

Work Cycle on Graveyard Shift

The work cycle on the third or graveyard shift differed from that on the other two shifts. The following additional duties were performed by the graveyard crew.

Pulling Casing

At the beginning of each graveyard shift, the two raise miners proceeded to the 1000-level hoist station and pulled casing from the drill hole. Usually 30 feet of casing was removed with a diamond-drill rig and chain block. Normally the bottom of the casing was maintained 10 to 40 feet above the face of the advancing raise. The headframe over the collar of the hole had been constructed a few inches too low; as a result the sheave wheel had to be removed before the 10-foot sections of casing could be uncoupled. The crew spent 2-1/2 to 3 hours of each graveyard shift pulling casing and traveling to and from the upper level.

Supplemental Mucking

The 1600-level station below the raise was quite small. Broken rock occasionally built up to such a height that the work cage could not be pulled back into the raise. As there was no motorman on the level after 2:00 a. m., the graveyard crew usually mucked several cars before pulling the cage upright in the station.

Supplemental Scaling

The cage was first hoisted to the back of the raise, where the crew proceeded to scale down the walls from top to bottom.

Extending Pipe

Besides the usual tools and materials, the graveyard crew also loaded the work cage with a jackhammer, cable, cable clamps, pipe clamps, and eyebolts; 30 feet of

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both 2-inch air pipe and 1-inch water pipe was lashed to the center column. The cage was then raised to the end of the permanent air and water lines, where the sections of new pipe were connected and secured against the rib. The crew also extended the blasting cable and performed other necessary repairs.

Drilling and Blasting

If time permitted, the cage was returned to the face, where the crew proceeded to drill, load, and shoot a standard raise round. The crew on graveyard shift often had time to complete one full cycle in the raise in addition to other duties.

Labor Requirements

The direct labor force for each shift on the project comprised a full-time, four-man raise crew plus a part-time motorman. The raise crew included a 1000-level hoistman, two raise miners, and a 1600-level nipper. The 1600-level mainline motorman served the raise as needed. The motorman and the 1600-level nipper loaded muck from the raise. Each complete cycle in the raise required approximately 1 hour of the motorman's time.

Drilling Practice

A standard, 6-foot, 17- to 22-hole, burn-cut, circular raise round (fig. 11) was drilled from the top deck of the work cage with medium-weight, self-rotating stopers. The stopers were equipped with 7/8-inch, quarter-octagon, alloy drill steel in 30-, 54-, 78- and 102-inch lengths with threaded, tungsten carbide, insert bits 1-7/8, 1-3/4, 1-5/8, and 1-1/2 inches in diameter.

A 3- to 5-hole burn cut was placed at one side of the face to reduce the possibility of blocking the central core-drill hole. The outside ring of holes was drilled from the edge of the top deck and flared so as to bottom about 6 inches beyond its circumference. All other holes in the round were drilled vertically into the back.

The initial raise rounds were drilled from the floor of the cage. Experience proved that the holes could be drilled faster and alined better if the top deck were used as a working platform. A few 8-foot rounds were attempted. These did not pull well in the soft porphyry and usually plugged the core-drill hole.

Performance data for drilling from the work cage are summarized in the appendix.

Loading and Blasting Practice

The standard raise rounds were charged with 50 to 75 pounds of 45-percent-strength, semigelatin dynamite. Neither the core-drill hole nor the center cut hole was loaded. Three to four, 1-1/8- by 16-inch cartridges were loaded in each of the other holes. The primer cartridge was loaded first. The holes were primed with 1 through 10 regular-delay electric blasting caps (fig. 11), which were wired in series and connected by lead wires to the permanent blasting line in the raise. The round was fired from the 1600 level with a capacitor-type blasting machine. The appendix includes data on the consumption of explosives.

Delays Encountered

The principal delays encountered in driving the raise are summarized below. The number and duration of the delays are indicated in the chronological log of the raising project that appears in the appendix.

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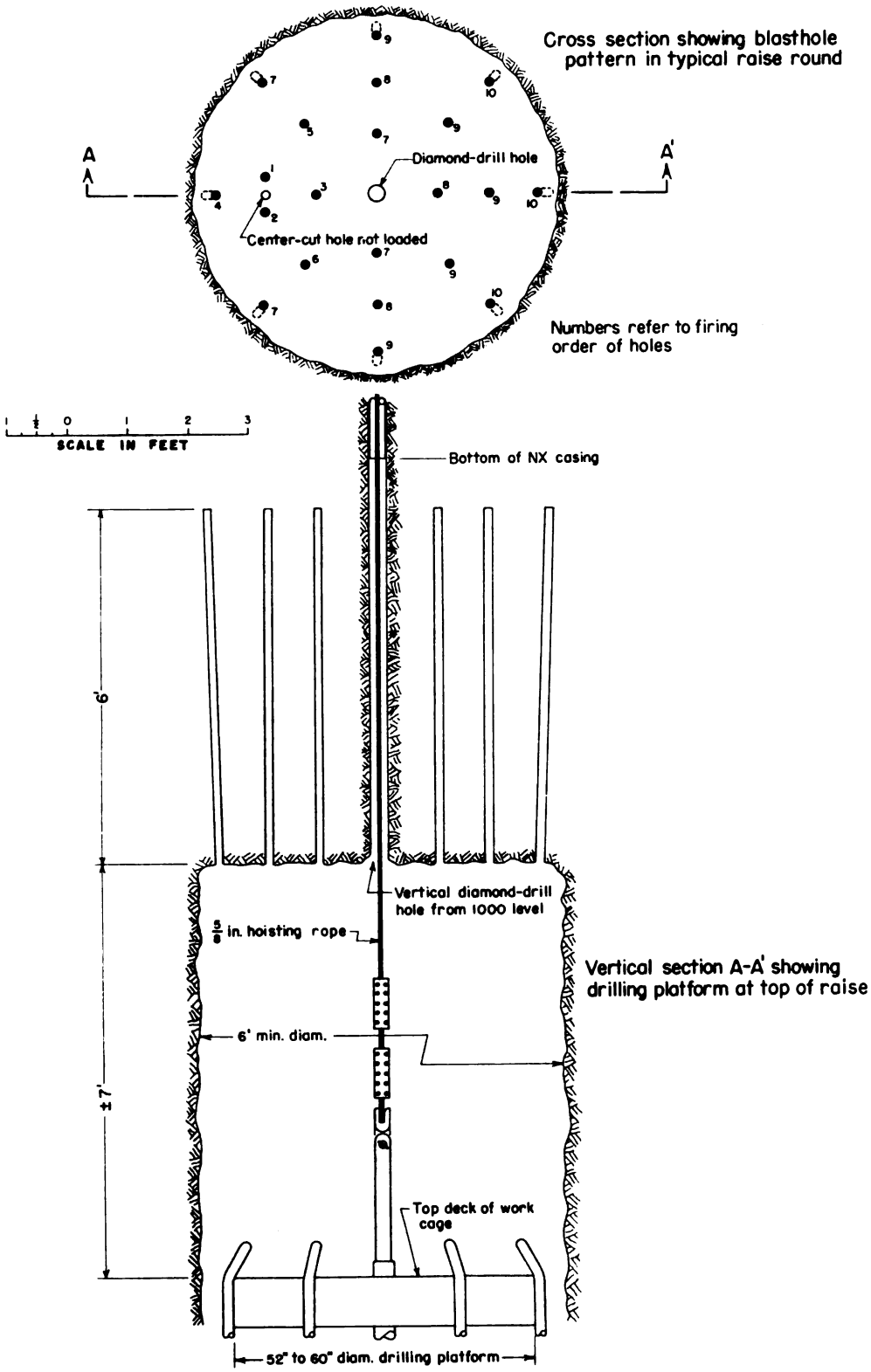
Cross section showing blasthole pattern in typical raise round
A
A'
Diamond-drill hole
Center-cut hole not loaded
Numbers refer to firing order of holes
SCALE IN FEET
Bottom of NX casing
6'
±7'
Vertical diamond-drill hole from 1000 level
5/8 in. hoisting rope
Vertical section A-A' showing drilling platform at top of raise
6' min. diam.
Top deck of work cage
52" to 60" diam. drilling platform

FIGURE 11. - Sections Through Top of Raise, Showing Typical 22-Hole, Burn-Cut Round Drilled From Work Cage.

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1. The core-drill hole was blocked by blasting on five occasions. Four occurred while the heading was still in a soft porphyry. A plugged hole usually could be attributed to an improperly drilled or loaded round. Reopening the hole caused only one major delay. In this case it was necessary to advance the face through the blocked section by conventional raising methods. Thereafter, the hole was opened more readily from the upper level. In one instance, two sticks of dynamite were lowered to the bottom of the hole and blasted. Twice the hole was cleared by a combination of water pressure and a chopping bit attached to diamond-drill rods. Another blocked section was reopened with water pressure alone.

2. The permanent air and water lines were installed along one side of the raise. Breakage of these lines due to falling rock caused considerable delay.

3. The electric signal cable suspended below the cage broke frequently owing to its weight. Moreover, it was particularly susceptible to damage from falling rocks during scaling.

4. The signal circuits on the cage were inadequately protected against moisture and frequently shorted during drilling.

5. The 1600-level station below the raise was quite small. If the muck pile on the level was too high, considerable time was lost in dragging the work cage back and alining it vertically in the raise. Often several cars had to be mucked before the cage could be suspended in the station.

COSTS

The overall costs of driving the 622-foot, raw ventilation raise averaged $50.50 per foot. This amount included $26.48 per foot for direct raising costs (labor, supplies, and repairs) plus $24.02 per foot for other expenses chargeable to the project (reaming and casing the core-drill hole, constructing the work cage, preparing the 1000-level hoist station, and guniting the finished raise). A detailed distribution of raising costs is included in the appendix.

The direct costs of driving the lower sections of the raise with the work cage averaged $36.91 per foot. The initial 1- and 2-shift operations in these sections were mainly experimental, therefore the cost was not representative. By the time the midpoint of the raise was reached, the technique of raising with the work cage had been fairly well established, most other operating problems had been solved, and a 3-shift operation was begun. As a result, the direct costs of driving the upper half of the raise were only $19.63 per foot. This figure is more representative of direct raising costs with efficient use of the cage method.

SAFETY

The raise was completed without a lost-time or even a trivial accident. The supervisory staff and crew felt that the most important factor in their safety record was thorough scaling down of the entire raise every day. The full length of the raise also was inspected each time a crew proceeded to the face.

The work cage was provided with positive-acting safety dogs in case of an emergency, but the need for them never arose. The dogs were designed to catch against the irregular walls of the raise if the hoisting rope should break. As a safety measure, tension was maintained on the hoist rope at all times, even when the cage was stopped at the top of the raise and blocked against the walls by means of the air jacks.

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The three independent methods of signaling from the cage contributed to safe and efficient completion of the raise. A nylon rope was carried at all times to provide the crew with an emergency means of escape if the cage were to "hang up" in the raise. The rope was never used. The cage also was provided with a spool of wire for pulling up small tools or supplies.

It was possible for a man to fall through the space between the sides of the cage and the walls of the raise. To eliminate this hazard when drilling was begun from the top deck, the crew was required to wear fireman-type safety belts. These belts were hooked to the hoisting rope in the space provided between the two torpedo clamps.

The company's experience indicated that the cage method of driving long raises probably was less hazardous than conventional methods owing to the following factors:

1. With the cage method of raising, the hazardous job of scaling down after blasting can be performed closer to the face and under more continuous and adequate cover.

2. In a raw raise driven with a work cage, it is impossible for broken rock to hang up on timbers, bulkheads, or ladders. Moreover, the hazards usually associated with broken or knocked-out timbers are eliminated.

3. Ventilation at the working face of a raise driven by the cage method is consistently better than at one driven by standard methods.

4. In a high raise without a hoist, the men often become fatigued climbing to the face and are more prone to accidents, particularly when working at high altitudes.

CONCLUSIONS AND RECOMMENDATIONS

The management and staff were pleased with the progress made and the safety record achieved with the cage method of raising. The method also proved cheaper than conventional raising. The company's initial experience with the method suggested the following ways in which its safety and efficiency might be improved:

1. The signal cable should be incorporated in the hoisting rope. A rope of this design is now being manufactured.

2. A drill hole large enough to hold the air and water pipe, hoist rope, signal cable, and possibly the blasting line would facilitate operations. A 6- to 8-inch-diameter hole would be preferable.

3. If a larger hole was not feasible, the permanent air and water pipe and the blasting line should be recessed in a slot excavated along the rib of the raise. This would help to protect the pipe and cable from falling rock and would prevent the cage from "hanging up" on the pipe and its supports while it was hoisted and lowered in the raise.

4. A large station is necessary below the raise to facilitate pulling the work cage into the raise over the muck pile.

5. Unless necessary because of unstable ground, casing the drill hole should be eliminated. The crew spent about 3 hours a day pulling casing and traveling to and from the upper level. This time was enough for completing a full cycle in the raise.

If the cage method of raising were repeated with the suggested improvements in design and technique, the management was confident that the crews could complete 6 full work cycles every 24 hours.

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APPENDIX

TABLE 1. - Chronological log of raising period

Date	Shifts worked	Man-shifts	Rounds completed		Holes drilled		Powder used, lb.	Remarks (other work performed, delays encountered, etc.)
			Number	Feet	Number	Feet		
April:								
15	1	4-1/8	1	8	17	136	75	Raising with work cage was begun 130 feet above 1600 level. First round plugged diamond-drill hole. Hole was filled to collar with water but failed to reopen.
16	1	4	-	-	-	-	-	Pointed steel rod bounced up and down in hole, with no results but to kink hoist rope.
17-20 ...	4	16	-	-	-	-	-	Stulled raise and installed ladders. Reblasted 4 bootleg holes from previous round.
22	1	4	1/3	8	6	48	17	Drilled from stulls around central diamond-drill hole. Blast reopened hole and drained standing water.
23	1	4						Replaced rope on hoist.
24	1	4-1/8	2/3	8	12	96	33	Cage used to remove stulls and ladders from raise and to drill remainder of round to square up face.
25	1	4-1/4	2	4-8	42	272	100	
26	1	4-1/8	1	6	12	72	37	Pulled casing.
27	1	4-1/8	1	6	13	78	50	
29	1	4-1/8	1	8	28	224	100	Round plugged diamond-drill hole. Two sticks of powder lowered to bottom of hole - blast reopened hole.
30	1	4-1/8	1	6	16	96	50	
Subtotal	14	57	8	-	146	1,022	462	Raise advanced 41 feet to a height of 171 feet above the 1600 level from Apr. 15-30, 1957.
May:								
1	1	4-1/8	1	6	26	156	50	
2	1	4-1/8	1	8	26	208	50	Round plugged diamond-drill hole.
3	1	4-1/4	2	6	30	180	100	Installed drill rig on 1000 level. Reopened hole with chopping bit and water pressure. Rods raised about 4 feet then dropped - repeated 12 times before hole cleared.
4	1	4-1/4	2	6	31	186	100	Hoist trouble. Broken nipple on bottom of cage.
6	1	4-1/8	1	8	18	144	75	Hole plugged - reopened in 3 hours with drill rig. Hoist trouble. Phone on cage out of order. Low air pressure.
7	1	4						Placed 180 feet of permanent air and water line in raise.
8	2	8-3/8	3	6-8	64	428	200	Broken bull hose.
9	2	8-1/2	4	6-8	95	666	287	Extended pipe.
10	2	8-3/8	3	6	65	390	225	Signal system out of order. Pulled casing.
11	2	8-3/8	3	6	68	408	225	Power failure - 2 hr. Air and water lines out - 2 hr.
13	2	8-3/8	3	6	64	384	150	Broken signal cable. Pulled casing.
14	3	12-1/2	4	6	85	510	225	Pulled casing, barred down raise, extended pipe.
15	3	12-3/8	3	6	64	384	175	Do.
Subtotal	22	91-3/4	30	-	636	4,044	1,862	Raise advanced 152 feet to a height of 323 feet above the 1600 level from May 1-15, 1957.
May:								
16	3	12-1/2	4	6	91	546	275	Smoke in raise. Repaired broken water pipe.
17	3	12-3/8	3	6	66	396	200	Hoist trouble. Replaced torn-out pipes - 8 hr.
18	3	12-3/8	3	6	68	408	225	Repaired broken water pipe and signal cable - 8 hr.
19	3	12-1/4	2	6	47	282	125	Changed gears on hoist - 4 hr. Repaired air and water pipes, signal cable, and blasting line - 6 hr.
20	3	12-1/2	4	6	93	558	300	Plugged drill hole - reopened with water pressure - 3 hr.
21	3	12-1/2	4	6	94	564	275	Broken air line.
22	3	12-5/8	5	6	109	654	350	Broken water line. Telephone on cage out of order.
23	3	12-5/8	5	6	107	642	300	Cut and reclamped hoist rope.
24	3	12-5/8	5	6	109	654	350	Signal cable broken.
25	3	12-3/8	3	6	65	390	225	Repaired air and water lines and signal cable - 9 hr.
26	3	12-1/2	4	6	84	504	275	Signal cable broken.
27	3	12-5/8	5	4-6	104	584	325	Repaired signal cable - 2 hr.
28	3	12-1/2	4	4-6-8	86	524	300	Repaired air line and signal cable - 3 hr. Phone out of order.
29	1/2	2-1/8	1	8	9	72	25	Final round drilled with jackhammer from 1000 level. Raise holed through to 1000 level at 11:00 a.m.
Subtotal	39-1/2	164-1/2	52	-	1,132	6,778	3,550	Raise advanced 299 feet to a height of 622 feet above 1600 level from May 16-29, 1957.
Grand total.	75-1/2	313-1/4	90	-	1,914	11,844	5,874	Raise advanced a total of 492 feet with work cage from Apr. 15 to May 29, 1957.

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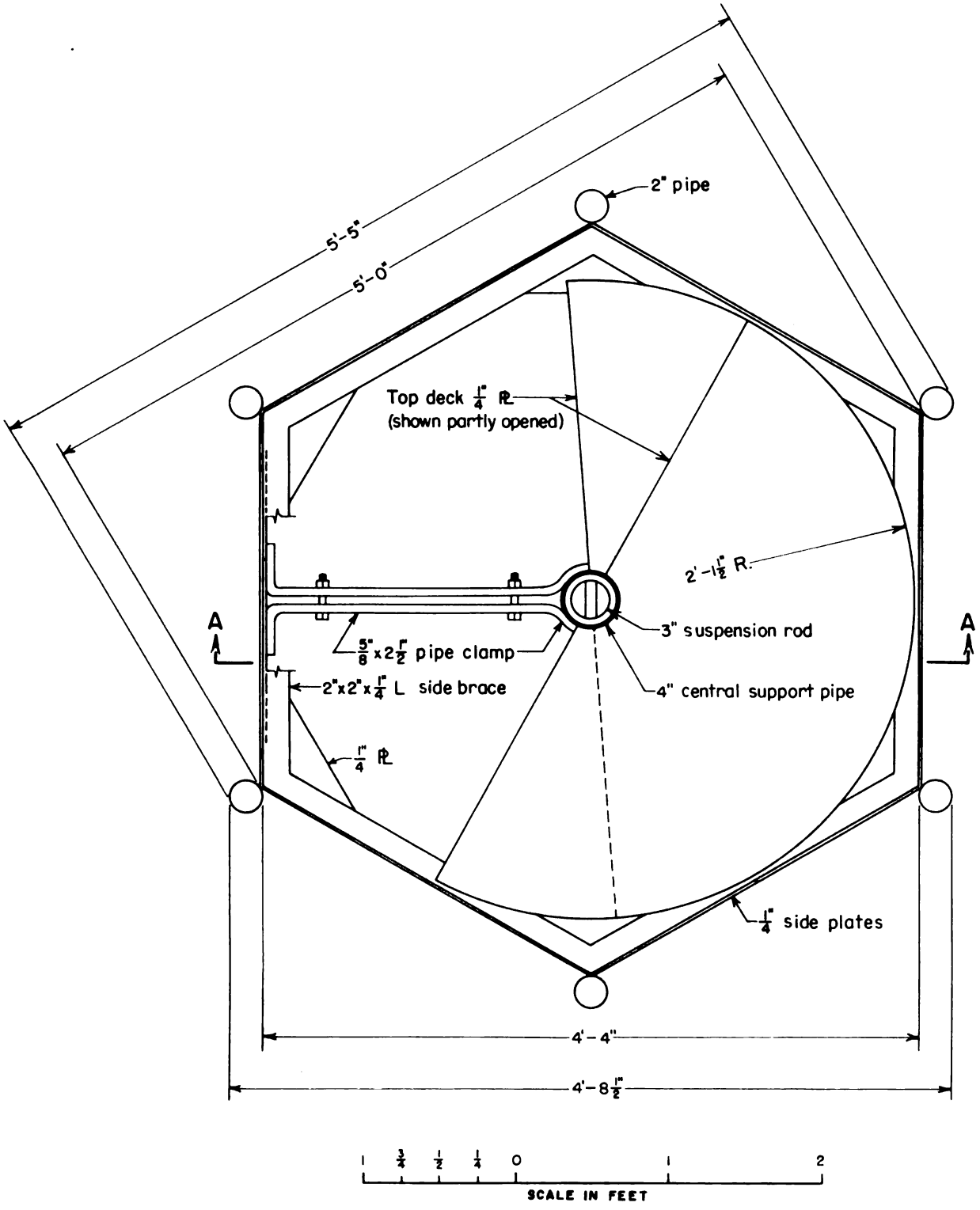

FIGURE 12. - Top View of Work Cage, Showing Pertinent Dimensions and Design Features.

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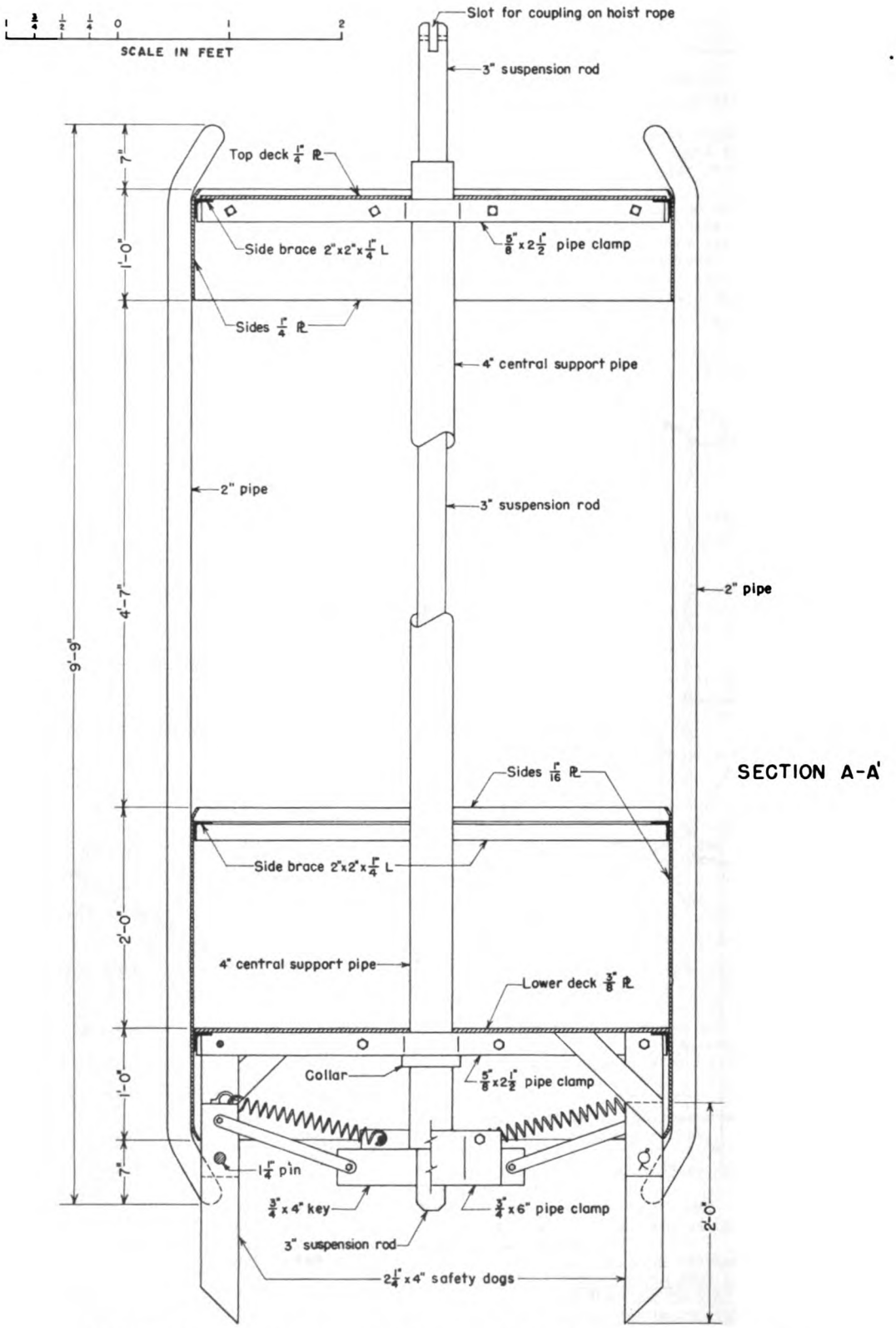

SECTION A-A'

FIGURE 13. - Idealized Vertical Section of Work Cage, Showing Pertinent Dimensions and Design Features.

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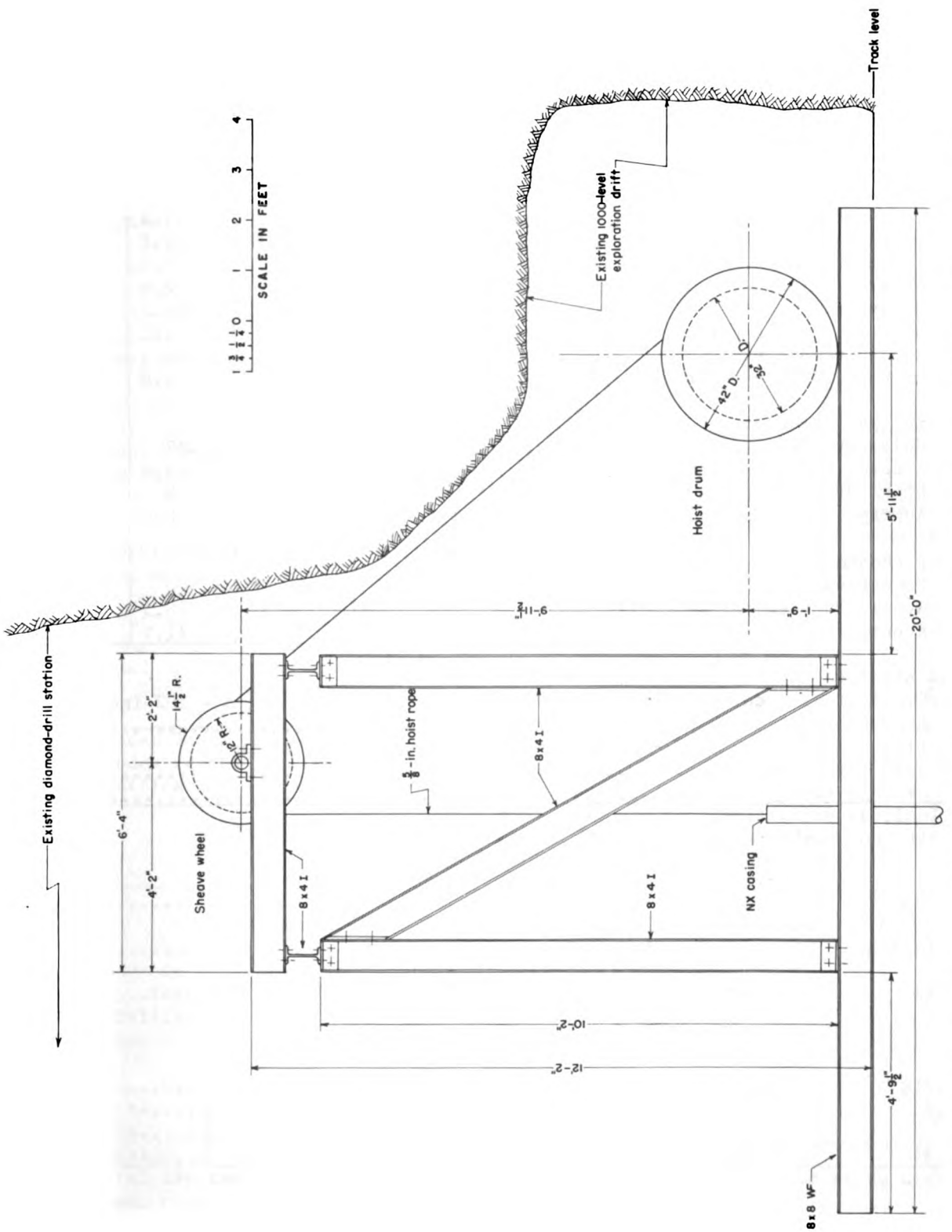

FIGURE 14. - Shop Drawing of Integral Headframe-Hoist Unit Erected in Existing 1000-Level Diamond-Drill Station.

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TABLE 2. - Operating efficiencies and performance data

(Calculations based on chronological log of raising period)

	Period			Total
	Apr. 15-30	May 1-15	May 16-29	Apr. 15 - May 29
Rates of advance:				
Rasising advance ..... feet	41	152	299	492
Days worked[1]	14	13	13.2	40.2
Average advance per day ..... feet	2.9	11.7	22.7	12.2
Shifts worked[1]	14	22	39.5	75.5
Average advance per shift ..... feet	2.9	6.9	7.6	6.5
Man-shifts worked[1]	57	91.75	164.5	313.25
Average advance per man-shift .... feet	0.7	1.7	1.8	1.6
Rounds completed	8	30	52	90
Average advance per round ..... feet	5.1	5.1	5.8	5.5
Drilling performance:				
Holes drilled	146	636	1,132	1,914
Average holes per round	18.3	21.2	21.8	21.3
Depth drilled ..... feet	1,022	4,044	6,778	11,844
Average depth per hole ..... do.	7.0	6.4	6.0	6.2
Powder consumption:				
Powder used ..... pounds	462	1,862	3,550	5,874
Average powder per round ..... do.	57.8	62.1	68.3	65.3
Average powder per foot of advance. do.	11.3	12.3	11.9	11.9
Drill steel and bit consumption:				
Drill steel used (26 - 30-inch, 16 - 54-inch, 20 - 78-inch, 8 - 102-inch)				70
Average footage per piece of steel				169.2
Bits used[2] (24 - 1-7/8-inch, 22 - 1-3/4-inch, 22 - 1-5/8-inch, 14 - 1-1/2-inch)				82
Average footage per bit				144.4

1/ Includes delay time.
2/ Bits not resharpened.

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TABLE 3. - Costs of driving a 622-foot, raw ventilation raise at Irene shaft, Leadville, Colo. (April-May 1957)

	Cost per foot of advance
Direct raising costs:	
Labor:	
Raising	$14.52
Hoisting	2.61
Nipping	2.47
Total labor	19.60
Supplies:	
Explosives	3.70
Drill steel, bits	1.50
Pipe, fittings	.61
Timber, matting	.15
Total supplies	5.96
Repairs:1/	
Hoist	.07
Signal cable	.62
Rock drills	.23
Total repairs	.92
Total direct raising costs	26.48
Other costs chargeable to raise:1/	
Reaming and casing diamond-drill hole	9.66
Construction of work cage	1.62
Preparation of 1000-level hoist station2/	5.75
Guniting completed raise	6.51
Overhauling hoist motor at end of project	.48
Total other costs	24.02
Total unit cost of raise	50.50

1/ Includes labor and supplies.
2/ Includes rehabilitation and ventilation of 1000 level, erection of headframe, and modification of hoist.

TABLE 4. - Comparison of direct raising costs for lower, middle and upper sections of raise

Section	Lower1/ (0 to 171 feet)	Middle2/ (171 to 323 feet)	Upper3/ (323 to 622 feet)	Total raise (0 to 622 feet)
Period	Before May 1, 1957	May 1-15,1957	May 16-29, 1957	April-May 1957
Total advance ....feet	171	152	299	622
Direct raising costs per foot:				
Labor	$22.09	$29.62	$13.08	$19.60
Supplies	6.36	5.80	5.82	5.96
Repairs	.74	1.49	.73	.92
Total	29.19	36.91	19.63	26.48

1/ Initial 130 feet of raise by conventional methods plus 41 feet of raise with work cage.
2/ 1- and 2-shift operations with work cage (experimental period).
3/ 3-shift operation with cage method after most problems were solved.

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